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Information is provided regarding the nature, magnitude, and extent of the emissions of boron. Background information concerning the basic characteristics of the boron industry has been assembled and included. Process descriptions are given, but they are brief, and are limited to the areas that are closely related to existing or potential atmospheric losses of the pollutant. The consumption of boron during 1969 was 85,864 tons, while domestic production totaled 171,361 tons. Imports and exports were 803 and 86,084 tons, respectively. Emissions to the atmosphere during the year were 11,003 tons. Nearly 22 percent of the emissions resulted from the processing of boron compounds, more than 34 percent from the manufacture and use of various end products, and about 43 percent from the combustion of coal. Emission estimates for processing and the manufacture of end use products are based on unpublished data obtained from industrial sources.

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REPORT

NATIONAL INVENTORY OF SOURCES AND EMISSIONS BARIUM, BORON, COPPER, SELENIUM, AND ZINC

1969

for

ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF AIR PROGRAMS
CONTRACT NO. 68-02-0100

BORON

SECTION II

by

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June 1972

PREFACE

This report was prepared by W. E. Davis & Associates pursuant to Contract No. 68-02-0100 with the Environmental Protection Agency, Office of Air Programs.

The inventory of atmospheric emissions has been prepared to provide reliable information regarding the nature, magnitude, and extent of the emissions of boron in the United States for the year 1969.

Background information concerning the basic characteristics of the boron industry has been assembled and included. Process descriptions are given, but they are brief, and are limited to the areas that are closely related to existing or potential atmospheric losses of the pollutant.

Due to the limitation of time and funds allotted for the study, the plan was to personally contact all of the mining and producing companies and about twenty percent of those in each major emission source group to obtain the required information. It was known that published data concerning the atmospheric emissions of boron were virtually nonexistent, and contacts with industry ascertained that atmospheric emissions

were not a matter of record. The boron emissions and emission factors that are presented are based on the summation of data obtained from production and reprocessing companies. Additional information was acquired during field trips to inspect the air pollution control equipment and observe processing operations.

ACKNOWLEDGEMENTS

This was an industry oriented study and the authors express their appreciation to the many companies and individuals in the boron industry for their contributions.

We wish to express our gratitude for the assistance of the various societies and associations, and to the many branches of the Federal and State Governments.

Our express thanks to Mr. C. V. Spangler, Project Officer, EPA, Office of Air Programs, Research Triangle Park, N. C., for his helpful guidance.

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SUMMARY

The flow of boron in the United States has been traced and charted for the year 1969 (Figure I). The consumption was 85,864 tons, while domestic production totaled 171,361 tons. Imports and exports were 803 and 86,084 tons, respectively.

Emissions to the atmosphere during the year were 11,003 tons (Table I). Nearly 22 percent of the emissions resulted from the processing of boron compounds, more than 34 percent from the manufacture and use of various end products, and about 43 percent from the combustion of coal.

Emission estimates for processing and the manufacture of end use products are based on unpublished data obtained from industrial sources.

TABLE I

EMISSIONS BY SOURCE
1969

Source Category	Source Group	Emissions - Tons	Emissions %
Mining		100	0.9
Processing		2,400	21.8
End Product Uses		3,783	34.5
	Glass	1,000	
	Ceramic Coatings	470	
	Agricultural Chemicals	1,800	
	Soaps and Detergents	13	
	Miscellaneous	500	
Other Emission Sources		4,720	42.8
	Coal	4,700	
	Sewage and Sludge	20	
TOTAL		11,003	100.0

TABLE II

EMISSIONS BY REGIONS

	Tons
Region No. 1	3,350
Region No. 2	3,690
Region No. 3	2,530
Region No. 4	1,433
TOTAL	11,003

Region No. 1

Arizona	Montana	Utah
California	Nevada	Washington
Colorado	New Mexico	Wyoming
Idaho	Oregon	

Region No. 2

Illinois	Michigan	North Dakota
Indiana	Minnesota	Ohio
Iowa	Missouri	South Dakota
Kansas	Nebraska	Wisconsin

Region No. 3

Alabama	Louisiana	Tennessee
Arkansas	Maryland	Texas
Delaware	Mississippi	Virginia
Florida	North Carolina	West Virginia
Georgia	Oklahoma	District of Columbia
Kentucky	South Carolina	

Region No. 4

Connecticut	New Hampshire	Pennsylvania
Maine	New Jersey	Rhode Island
Massachusetts	New York	Vermont

EMISSION FACTORS

The emission factors presented herein are the best currently available. They were determined through a combination of methods consisting of: (1) direct observation of emission data and other related plant processing and engineering data; (2) estimates based on information obtained from literature, plant operators, and others knowledgeable in the field; (3) calculations based on experience and personal knowledge of metallurgical processing operations; and, (4) specific analytical results where available.

The basic data used to calculate the emission factors are contained in the files of the Contractor.

TABLE III

EMISSION FACTORS

Mining	1 lb/ton boron mined
Processing	28 lb/ton boron processed
End Product Uses of Boron	
Glass Manufacture	70 lb/ton boron processed
Ceramic Coatings	80 lb/ton boron processed
Other Emission Sources	
Coal	18 lb/1,000 tons of coal burned
Sewage and Sludge	55 lb/1,000 tons of sewage and sludge burned

MINERAL SOURCES OF BORON

Boron (B) is a black or brownish powder in the amorphorus form and a black, hard, brittle solid in the crystalline form. It melts at about 2,300 C and has an atomic weight of 10.82.

In nature boron occurs only in combined forms, usually as an alkaline earth borate or as boric acid. It is widely distributed in the earth's crust, but there are only a few large deposits that are commercially valuable. About half of the indicated world reserves and in the sodium borate deposits and brine lakes of California. Other important reserves are located in Turkey and the U.S.S.R. Minor domestic deposits occur in Oregon and Nevada.

Most of the domestic boron production comes from a mine in Kern County, California, that is owned and operated by the U. S. Borax and Chemical Corporation. The remaining production is a by-product of mineral recovery from Searles Lake brines.

MATERIAL FLOW THROUGH THE ECONOMY

The domestic sources and uses of boron during 1969 are shown in Figure I. The production was 171,361 tons (B content), approximately half of which was consumed in the United States while the other half was exported. During the year imports were 803 tons and industry stocks were increased about 216 tons.

The most important application of boron during 1969 was in glassmaking. Nearly 34 percent of the domestic consumption was used in producing glass and glassware, principally for strengthening the product. About 16 percent was used in soaps and detergents, and nearly 14 percent in ceramic coatings applied to household and industrial appliances and pottery. More than 13 percent was an ingredient in agricultural chemicals, added to fertilizers to supply boron as an essential plant nutrient, or used in formulations for extermination of weeds.

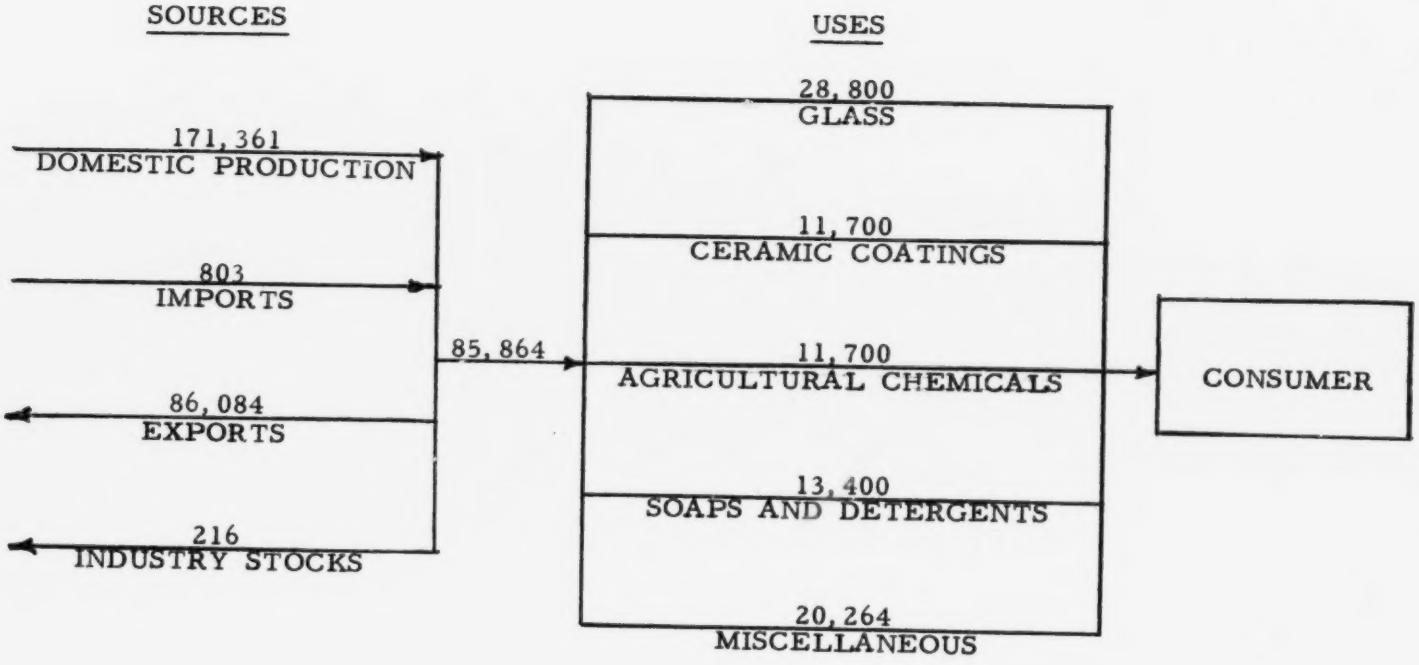
Other applications requiring smaller quantities included the use of boron in fluxes, in compounds used as catalysts, in adhesive additives for latex paints, as fire retardants in plastics, in motor fuel additives to suppress preignition firing,

as an absorber material in nuclear reactors, as a deoxidizing agent in nonferrous metallurgical reactions, in compounds for alloying steels, and numerous miscellaneous uses.

BORON

MATERIAL FLOW THROUGH THE ECONOMY - 1969

(Short Tons - B Content)



Data Source - U. S. Bureau of Mines

Figure I

USES AND EMISSIONS OF BORON

MINING

About 70 percent of the world's supply of boron is recovered from bedded deposits and lake brines in the Mojave Desert in southeastern California. In Kern and Inyo Counties, sodium borates are mined by the major producer, United States Borax and Chemical Corporation, employing open-pit methods. In San Bernardino County, the borates are extracted from Searles Lake brines by 2 companies, Kerr-McGee Chemical Corporation and Stauffer Chemical Company.

At the large open-pit mine near Boron, California, ore is mined using explosives and electric shovels. It is then moved to the surface and on to the nearby concentrating and refining plants by trucks and an automatic ore belt conveyor system that starts in the pit at the 225 foot level.

Atmospheric emissions of boron at the mine are in the form of sodium borate with the size ranging from about 0.5 to 20 microns, the principal emissions occurring in connection with blasting, loading, unloading, hauling, conveying, and crushing. Air pollution control equipment consists of bag

filters for the primary and secondary crushers.

Searles Lake consists of a salt body with an area of more than 30 square miles. About 45 percent of the volume of the deposit consists of a saturated brine that fills spaces between clusters of salt crystals. The surface of the lake is usually dry, but the brine level never falls more than a few inches below the surface.

Wells have been drilled in the lake to the desired depths and the brine is pumped from them to the processing plants. During mining, the boron is always in solution in the brines and there are no detectable emissions to the atmosphere.

The Contractor's estimate of boron emissions to the atmosphere from sources of mining is 100 tons for the year 1969.

PROCESSING

The borate minerals currently mined in Kern County, California, are principally borax (tincal - $Na_2B_4O_7 \cdot 10\ H_2O$), a sodium borate with 10 molecules of water, and kernite ($Na_2B_4O_7 \cdot 4\ H_2O$), a sodium borate with 4 molecules of water. Both these minerals must be processed to remove impurities during the production of the primary commercial compounds sodium tetraborate decahydrate ($Na_2B_4O_7 \cdot 10\ H_2O$), sodium tetraborate pentahydrate ($Na_2B_4O_7 \cdot 5\ H_2O$), and anhydrous sodium tetraborate ($Na_2B_4O_7$).

Since the ore in Kern County arrives at the processing plant in a dry form, the refining starts with ore dissolving and impurity removal, followed by recrystallization and drying. Some of the material is crystallized and produced as decahydrate, some as pentahydrate, and the remainder fused in a furnace to the anhydrous state.

When the crushed ore is received it is mixed with a weak borax liquor from the refinery and heated to near the boiling point in steam-jacketed tanks. As the borax is dissolved insoluble impurities are removed by screening, sedimentation, and filtration.

The hot, muddy liquor then enters the first of 4 thickeners. The underflow from the first thickener goes successively to the second, third, and fourth, each time being washed with a more dilute borax solution. The overflow from the first thickener is filtered and pumped to vacuum crystallizers to produce sodium tetraborate decahydrate or sodium tetraborate pentahydrate. Crystals are separated from the slurry of borax pentahydrate or decahydrate in automatic centrifuges.

From the centrifuges the crystals are dried in 3 rotary driers and 7 Wysmont Turbo driers equipped with revolving trays in which the borax is raked from one to the next. The dried borax crystals are stored prior to sale or shipment to other divisions for production of boric oxide, boric acid, anhydrous borax, and specialty products.

At Searles Lake the first processing steps are somewhat different than in Kern County. When the sodium borate is received it is already dissolved. It is in the brine pumped from the lake and the average concentration is about 1.5 percent. The dissolving step is not required but there is an excess of water that must be removed.

The principal processing steps are evaporation, crystallization,

recrystallization, and drying. In the evaporation process, brines are fed into evaporators where sodium salts crystallize and are removed, leaving only potassium and borate components of the brine in the liquor. The liquor is then cooled in continuous vacuum crystallizers to crystallize potassium chloride. During this period, the solution becomes supersaturated with respect to borax. It is sent through crystallizers, thickeners, and centrifuges. Moist borax then goes to driers which discharge dried borax ready for any further processing into boron chemicals.

Anhydrous sodium tetraborate may be produced from either wet or dry sodium tetraborate decahydrate. In one process the decahydrate is first calcined, which creates some dusting. These dust-laden exhaust gases pass through a cyclone separator and into wet scrubbers. The dust collected in the separator is added to the calciner discharge which then goes to the fusion furnaces. Each fusion furnace is cylindrical in shape and has a gap of about 8 inches between the bottom edge of the furnace firebox and the inner edge of the water-cooled furnace bottom. The calcined borax is fed continuously into this bottom area of the furnace, where it becomes molten and can flow out the furnace tap. Anhydrous borax

usually remains in the amorphous form when it is cooled by running the molten borax between large water-cooled rolls. This operation forms thin sheets which are crushed and screened to desired particle size. Some crystalline anhydrous borax is desired by manufacturers and it is produced by cooling the molten borax in bucket molds to form ingots, then crushing the ingots.

Other compounds made at some of the primary refineries include boric acid (H_3BO_3) and boric oxide (B_2O_3). Boric acid is an important compound because it is the raw material for making boron carbide, metal borides, boron alloys, and ferro-boron. It also has a wide range of industrial uses.

By one method of manufacture, granulated borax or a hot saturated solution of borax from the refining plant is charged into a reaction vessel. Then sulfuric or hydrochloric acid is added to produce an acidic solution. When the solution is cooled, boric acid crystals can be removed by filtration. This crude boric acid may be further refined by one or more recrystallizations from water. Other manufacturing methods are similar to the one described as they involve solutions which are crystallized in evaporators.

Boric oxide, practically an anhydrous form of boric acid, can be made by heating finely ground boric acid slowly to about 500 F in a vacuum and maintaining the temperature for 6 hours. Another form of boric oxide may be produced by heating boric acid in a loosely covered container at 440 to 480 F for several days.

Boron carbide and metal borides account for about 16 percent of the boron used during 1969. Because of its self-bonding characteristic, boron carbide can be molded in graphite and pressed at temperatures up to 4,300 F into high-density, non-porous shapes. Lower density shapes may be prepared by cold-molding and sintering.

The most common method of producing boron carbide is the reduction of boric oxide by carbon at temperatures between 2,500 and 4,200 F. The reaction can be accelerated by using fine carbon particles, such as carbon black, and by intimate mixing of the boric oxide and carbon. The reduction of boric oxide with magnesium in the presence of carbon also yields boron carbide, but the product must be washed free of magnesium oxide with hydrochloric acid and then further purified by boiling in hydrofluoric and nitric

acids. The other production methods are unprofitable for commercial quantities and are used to produce very small amounts of a high-grade product.

The metal borides may be made by a number of general methods. One of the most economical and widely used is the reduction of boric oxide and the metal oxide with a reducing agent such as aluminum, silicon, magnesium, carbon, boron, or boron carbide. There can be a direct reduction of metallic boron with the metal at temperatures between 2,000 to 3,600 F. Other methods include electrolysis of fused-salt mixtures containing metal and boron oxides, and deposition from the vapor phase.

While this study was in progress, information was obtained from the 3 companies that produce commercial borax and other boron compounds. Meetings were held with 2 and data were received by correspondence from all 3. The information included details concerning the use of air pollution control equipment, as shown in Table IV, and data regarding particulate emissions. During the processing of borax the boron emissions that occur are sodium borate in various degrees of hydration, primarily from one to 3 mols hydrate.

TABLE IV

TYPICAL APPLICATIONS
AIR POLLUTION CONTROL EQUIPMENT

Procedure	Control Equipment
Borax refining	Cyclone, scrubber, and baghouse
Anhydrous borax	Cyclone, scrubber, and baghouse
Borax calcining and melting	Cyclone, baghouse, and electrostatic precipitator
Boric acid drying	Cyclone and scrubber
Borax drying	Baghouse
Borax screening	Baghouse
Borax dehydration	Cyclone and electrostatic precipitator
Borax packing	Cyclone and baghouse
Dehydrated borax packing	Baghouse
Dehydrated borax grinding	Baghouse
Boric oxide production	Scrubber and baghouse
Boron trichloride production	Scrubber
Boron tribromide production	Scrubber

Other emissions that occur are boric oxide, boric acid, and sodium pentaborate as those compounds are being produced. Particulate size has been reported to range from less than one to as much as 45 microns.

Boron emissions have been reported to vary considerably from plant to plant, ranging from 0.2 to 40 pounds per ton of product. During 1969 emissions to the atmosphere resulting from the production of commercial borates and boron compounds totaled 2,400 tons.

END PRODUCT USES OF BORON

Glass

Borates, including borax, boric acid, and boric oxide, are important as raw materials for the glass industry. They make glass more brilliant and more resistant to breakage from impact or sudden temperature change. The inclusion of borates in glass batches has been found to facilitate production by lowering the liquidus temperature, increasing the rate of melting and refining, and increasing the furnace production. Borates are also used in fiber glass products such as glass cloth, boat hulls, insulating materials, automobile bodies, containers, building panels, aircraft sections, and numerous molded articles. Currently, the glassmaking industry is the largest single user of boron in the United States.

Raw materials for glass manufacture are shipped in packages or in bulk and unloaded by manual labor, vibrator-gravity, drag shovels, or vacuum systems. Methods of material storage vary widely, but in large installations the raw materials for the glass mix are often stored in gravity feed storage hoppers and are fed directly to the weighing and mixing room. *Minor ingredients are usually stored in their original*

containers. Cullet (waste glass or rejected ware to be re-melted) must be transported to an area where it may be segregated by type.

Glass batch mixing systems range from full automation to hand operations. Most mixers are of the rotating-barrel type which tumble the batch upon itself in a revolving drum. During a batch mixing process the materials are dry or nearly dry, which results in a loss by dusting. The glass furnace charging may be done manually or automatically, and continuously or intermittently.

Basically, the manufacture of glass is a high-temperature conversion of raw materials into a homogenous melt for the fabrication of useful articles.

There are 3 types of melting units used in the glass industry. Clay "pots", which may be open or covered, are used where quantities or special compositions do not justify the use of a tank. This process involves a relatively high proportion of manual handling, The day tank handles batches up to several tons. Finally, most glass is melted in large, direct-fired, regenerative type furnaces. Raw materials are charged at one end of the furnace and molten glass is pulled from the

other end. Glass temperatures are as high as 2,700 F in the furnace, but usually 2,220 F at the discharge.

There are 2 principal sources of particulate matter in the furnace exhaust gases: raw materials entrained in combustion gases, and materials from the melt. Particulates expelled from the furnace are the result of many physical and chemical reactions that occur during melting. The reactions are so complex that prediction of losses cannot be based on temperature and vapor pressure data alone. One significant factor affecting the quantity of particulates is the production rate. As the production rate of the furnace is increased, the particulates also increase in quantity.

Following melting there are several ways to accomplish the forming of glass. Glass may be blown, pressed, cast, rolled, or drawn. Glass fibers may be made continuously by mechanical drawing, and a glass to be pulverized is dribbled or ladled into water to produce "dry gage" glass.

Final glass operations are principally finishing and secondary forming. Finishing operations may include any one or combination of the following: flame cut-off, sawing, score and break, score-thermal crack off, drilling, grinding, polishing,

engraving, acid etching, glazing, and sealing. Secondary forming operations may then be used to produce difficult shapes. Before the glass becomes a finished product, a final treatment of tempering or staining may be required.

Many of the people in the glass industry who were contacted during this study provided general information concerning glassmaking, the use of boron compounds, methods of operation, and air pollution control equipment, but only one company provided specific data regarding boron emissions to the atmosphere.

Based on emission data obtained from this one company, boron emissions to the atmosphere during 1969 are estimated at 70 pounds per ton of boron used in the manufacture of glass. In the United States, boron emissions during the year totaled approximately 1,000 tons.

Ceramic Coatings

Porcelain enamel is a bright, colorful ceramic coating that is applied on metal to provide both decoration and surface protection. It is a finish commonly used on many household and industrial products such as stoves, refrigerators, freezers, washing machines, sinks, bath tubs, and building

panels. The coating called enamel slip is essentially a water suspension of clay and frit. It is applied to the metal and fired in a furnace at high temperature to produce a hard glass-like finish. Ceramic glaze is a similar ceramic coating applied to glass or pottery.

The frit is a shattered glass which is the chief component of porcelain enamels and ceramic glazes. It is manufactured on customer order for specific end uses and the composition of the production mix varies widely. In most mixes borates are added in varying amounts to make the coating brighter, more resistant to cracking, and easier to apply.

From the standpoint of air pollution, the principal emissions of boron from the production and use of ceramic coatings are those that occur during the manufacture of the frit. The most significant dust and fume emissions are due to the smelting operation. In the fritting process, inorganic chemicals and minerals are removed from storage in weighed increments according to formula, dry mixed in a rotary blender, and charged into smelting furnaces. The minerals and chemicals fuse and react to form a glass. When the glass in the furnace reaches a predetermined physical and chemical

state, it is removed and shattered either by passing it through a bath of cold water or by passing it through water-cooled rolls. The final production steps include either drying or cooling, and then bagging. There are dust emissions due to handling the raw materials as they are received, stored, measured, and mixed prior to charging the smelter. The ingredients in the charge are mostly refractories, including quartz, feldspar, and clay, plus mineral fluxes such as borax, soda ash, fluorspar, litharge, and cryolite. These fluxes react with the refractories to form the molten glass.

The atmospheric emissions of boron during frit smelting consist primarily of oxides in vapor form and in particulates. The magnitude of emissions varies considerably depending upon the amount of boron in the charge, the combination of ingredients, and the type of smelter. As the boron content of the mix is increased, the boron emissions also increase. However, as larger proportions of fluorspar and other similar ingredients are added, they react with boron reducing the emissions.

Rotary and crucible smelter emissions are somewhat more difficult to control than those from a smelter of the hearth type. The rotary unit is cylindrical, can be rotated in

either direction, and can be tilted vertically. It is open at one end for the introduction of fuel and combustion air. It is open at the opposite end for the discharge of flue gases and for charging raw materials. Smelters of this type require a detached canopy hood properly suspended above the unit so that exhaust gases will be trapped and prevented from escaping into the manufacturing plant.

The crucible smelter is a refractory or fireclay container mounted within a circular steel shell that is insulated and supported by trunnions in a manner which allows it to be tilted for the pouring operation. A canopy hood is required if the discharge gases are to be collected and vented through air pollution control equipment.

The hearth smelter does not require a hood. It is a stationary unit with an exhaust gas outlet that may be directly connected to a dust collecting system.

Several people in the ceramic industry were contacted during this study and information was obtained regarding the fritting process, the use of boron compounds and other ingredients, the types of smelters, and air pollution control equipment. Two industrial sources provided specific data regarding

boron emissions to the atmosphere from smelting furnaces. Based on the emission data obtained from these 2 companies, boron emissions to the atmosphere during 1969 are estimated at an average of 80 pounds per ton of boron used in ceramic coatings. In the United States boron emissions during the year totaled about 470 tons.

Agricultural Chemicals

Boron in the soil is essential to healthy plant growth, and most soils under cultivation for a long period of time have become deficient in this element. A lack of boron in the soil may cause corkiness in apples, cracked stems in celery, deformed heads of cauliflower, low yields, stunting, and discoloration in many crops and trees. In very small quantities it is an ingredient of complete, balanced, artificial fertilizers; however, care must be used in adding boron, for when it is used in large amounts it acts as a nonselective herbicide.

Certain borates are widely used on railroad rights-of-way, airport runways, factory sites, lumber and oil storage yards, and other places where plant growth is a nuisance and a fire hazard. A new development is to use boron for

growth control rather than growth elimination. By stopping growth without killing the vegetation, freeway borders, center strips, and other similar areas may be maintained at the desired growth level without pruning or mowing, thereby saving the cost and the danger of performing these operations in heavy traffic.

Borates are used in solutions as a wash for certain citrus fruits to inhibit the formation of molds. They are also used as insecticides in the control of fly larvae in the poultry industry, and of dog and swine hookworm larvae.

Emissions to the atmosphere due to the use of boron in agricultural chemicals occur principally when the products are applied as sprays or dusts. The various factors affecting the application have been discussed in the literature at great length: the droplet size, the spray drift, the fluid properties, the meteorological factors, the air movement, the nozzle types, the evaporation, and numerous other subjects. A wealth of general information has been published, but there is virtually none that is specific regarding the amount of spray or dust that is not effective. The pesticide industry merely replies that there are too many factors

involved to estimate overall emissions with any degree of accuracy; however, one manufacturer did indicate that less than 2 percent of the recommended dosage is required for effective application. Obviously, it is expected that a large part of the spray or dust will not contact the vegetation or the insects. Most of it will evaporate, drift, or fall on the ground.

In order to estimate emissions, the problem was discussed with people knowledgeable in the field of pesticide application. In most instances they were reluctant to estimate atmospheric emissions, however, a few did express an opinion. As a result, the Contractor's estimate of boron emissions to the atmosphere due to the use of agricultural chemicals during 1969 is 1,800 tons including losses during formulation, spraying, and dusting.

Soaps and Detergents

Borax adds to the cleaning power of soaps and detergents. It controls alkalinity, freshens and deodorizes, aids in removal of certain stains, and is mildly antibacterial. It is used in detergents, scouring cleansers, liquid cleaners, shaving cream, tooth paste, and talcum powder.

Sodium borates are one of the components used in the formulation and manufacture of some household synthetic detergents. These spray-dried detergents are made by mixing formula quantities of the various components as a slurry. Some ingredients are wet and others are dry as they are fed to the process. The slurry from the mixer is pumped at high pressure to the spray drying tower where it is sprayed into a stream of drying air. As the slurry falls through the air, most of the moisture is removed and detergent granules are formed. Effluent air from the drying operation is discharged through wet scrubbers and/or bag collectors.

Scouring cleansers and talcum powder are manufactured by dry mixing formula quantities of the required ingredients prior to packaging. Manufacturers advise there are no air emissions from these processes and dusting is not a problem. Air pollution control equipment is not used in connection with these processes.

Liquid cleaners are formulated by agitating measured quantities of wet and dry components together in a tank. Batches are transferred to holding tanks and then delivered to the filling operation. Atmospheric emissions, if any, are

negligible and air pollution control equipment is not required.

Both shaving cream and tooth paste are products that are produced in a similar manner and they may contain boron. However, their production is relatively unimportant from the standpoint of air pollution. Most of the processing is done with the ingredients in a wet or damp condition.

While this study was in progress, emission data and related information was obtained concerning 21 soap and detergent manufacturing facilities. Sodium perborate, sodium tetraborate, and sodium borohydride are reported to be the boron compounds in the particulate emitted to the atmosphere, and the particle size is thought to be within a range of one to 10 microns. Based on data from 4 manufacturing plants, the boron emissions to the atmosphere during 1969 averaged 2 pounds per ton of boron processed. Based on this emission factor, the atmospheric emissions of boron in the United States during the year totaled approximately 13 tons.

Miscellaneous

In addition to the major applications discussed above, boron is used for many miscellaneous purposes. It is found in many lubricating oil additives and in certain gasoline additives

where it is claimed to prevent preignition, help prevent formation of sludge in the engine, and give extra power. It has been considered as a high energy jet and missile fuel, but that development program has been discontinued. However, it is used as a jet fuel additive to kill bacteria and fungus in fuel tanks and lines. It is also an ingredient in additives for antifreeze and hydraulic brake fluids where its purpose is to act as a corrosion inhibitor.

Other than in the transportation field applications of boron include those in pharmaceuticals, cosmetics, photographic chemicals, termite control, flameproofing for building materials, fluxes, adhesives, glues, starches, sizing, wire drawing, extra hard abrasives, leather tanning, treatment of brain tumors, soldering, brazing, welding, anodizing aluminum, electrolytic condensers for electronic equipment, nuclear reactors, alloy steels, wash solutions for citrus fruits, plastics, paints, and nonferrous metallurgy.

In the steel industry boron has become an important alloying element to increase the hardenability of steels. Ferroboron is generally used for this purpose since it dissolves rapidly in molten steel, providing better distribution and

more accurate additions. Boron is usually added in ferrous alloys in amounts up to 0.003 percent, but higher amounts may be used in the production of very hard cutting tools. As little as 0.001 percent boron accelerates the annealing time of malleable iron castings.

In nonferrous metallurgical operations boron is used as a deoxidizer and degasifier. It is an especially good cleansing agent for refining gold and silver, and also a good grain refiner for aluminum.

Borax, boric acid, and sodium metaborate all find varied and special applications in the manufacture of photographic supplies. Borates are components of photographic developing chemicals for film and paper; however, wet processes are used during manufacture.

Boron nitride finds use in the manufacture of crucibles and heat-resistant products. It is found in thermal insulation in high-frequency induction furnaces, in electrical insulators for high voltages, and as a coating on electrode holders in automatic welding. It may be prepared by heating boric oxide or boric acid with sodium cyanide, potassium cyanide, calcium cyanide, calcium cyanamide, ammonium chloride,

or by heating boric oxide with ammonia.

Water solutions of borax are commonly used in dyeing leather and textiles, in cleansing hides and skins, to prevent mildew in plasters, and to give a high gloss to starches. Other preservative applications are found in the cosmetic and pharmaceutical industries where boron compounds are used in face creams, talcum powder, medicated gauzes, and special medicines.

Boron carbide is useful as an abrasive and refractory material. Because of its thermal properties many jet aircraft, rocket, and gas turbine parts are made of this compound. The metal borides have high thermal and chemical stability and are suitable for cutting equipment, nuclear control devices, long-lasting cathodes, and electronic devices.

Although more than 100 industrial companies were contacted during this study regarding the reprocessing of boron and boron compounds, very little information was available concerning the magnitude of emissions resulting from the miscellaneous uses of boron.

The Contractor's estimate of boron emissions to the atmosphere

due to miscellaneous uses totaled 500 tons for the year 1969. Information obtained from 7 companies was used as a basis for this estimate. Even though they did not report emissions, the information furnished concerning processing was helpful.

SOURCES OF INADVERTENT BORON EMISSIONS

COAL

In order to estimate boron emissions due to the burning of coal it has been necessary to determine the boron content of the coal, the quantity of boron in the fly ash, and the amount of coal fired, as well as the degree of application and the efficiency of air pollution control equipment in service during 1969.

Numerous samples of coal from various regions of the United States have been analyzed and the results reported by several investigators. The data shown in Tables V and VI are from 2 of the published reports which show the boron concentration in domestic coal averages about 59 ppm.

When firing coal, part of the ash is discharged from the furnace as fly ash and part as bottom ash. The fly ash averages about 65 percent of the total ash and is carried from the furnace by the flue gas, usually through a cyclone-type dust collector or an electrostatic precipitator, then discharged to the atmosphere. It is estimated that 90 percent of the coal

is fired in units that are equipped with some type of air pollution control system, and the average efficiency of control is 85 percent.

Calculations have been made based on:

(a) 516,084,000 tons of bituminous and anthracite coal consumed in the United States during 1969 [1];

(b) an average boron content of 59 ppm;

(c) fly ash 65 percent of total ash;

(d) 85 percent efficiency of control, and

(e) 90 percent application of control.

The boron emissions in the United States during 1969 calculated by this method totaled 4,700 tons.

$$516,084,000 \times 59 \times 10^{-6} \times 0.65 \left[1 - (0.85 \times 0.90)\right] = 4,700$$

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1 Minerals Yearbook. Bureau of Mines; 1969.

TABLE V

AVERAGE MINOR ELEMENT CONTENTS OF COALS FROM VARIOUS REGIONS OF THE UNITED STATES - PPM

Region	Ash Content of Coal - %	B Content of Coal - ppm
Northern Great Plains	13.42	116
Eastern Interior	6.16	96
Appalachian	6.11	25
Western and Southwestern	NR*	33
Average Boron Content in Coal		67

*Not reported

NOTE - The above table based on Geological Survey Bulletins 1117-C and 1117-D; 1966 and 1967.

TABLE VI

AVERAGE BORON CONTENT IN ASH OF COAL

Region	Frequency of Detection - %	B Content of Ash - %	Ash Content of Coal - %	B Content of Coal - %
Eastern Province	100	0.0265	9.3	0.0025
Interior Province	100	0.0731	10.5	0.0077
Western States	100	0.0529	9.8	0.0052
Average Boron Content of Coal				0.0051

NOTE The above table based on "Spectrochemical Analyses of Coal Ash for Trace Elements" Bureau of Mines RI 7281; Table 1, July 1969.

OIL

In order to estimate boron emissions to the atmosphere due to the combustion of fuel oil, it is necessary to determine the boron content and the quantity of oil received from numerous foreign and domestic sources. Information was located showing the analyses of 120 samples of domestic crude; however, the situation was different with respect to residual oils and foreign crude. The only reliable information available on residual oil was that regarding nickel and vanadium.

Due to the lack of reliable data, there is no estimate of emissions set forth in this report other than a suggested range of values. Based on the Contractor's studies of other metal emissions due to the burning of fuel oil, boron emissions should range between 2 and 40 tons for the year 1969.

SEWAGE AND SLUDGE

A recent report concerning the burning of sewage and sludge indicates the present burning rate in the United States is about 2,000 tons per day [1]. Based on a boron content of 30 ppm [2], the atmospheric emissions currently are about 20 tons of boron per year.

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1. Private communication from the Federal Water Pollution Control Authority.

2. International Research Group on Refuse Disposal. Information Bulletin No. 8 Mar., 1960.

UPDATING OF EMISSION ESTIMATES

The emissions and emission factors presented in this report are the result of calculations based principally on information obtained from industrial sources. They are specifically for the year 1969, but may be updated at any time when additional information is available. Either of the 2 methods described herein may be used for updating; however, the longer procedure, referred to as Method A, will yield results that are much more reliable.

The procedures to be followed with Method A are essentially the same as those used during the original study, which are described briefly as follows. More than 130 inquiries were sent to processing and reprocessing companies by mail or delivered during personal visits to plant sites. There was no reply from 56 companies. Another 38 companies answered but did not provide data. There were 36 companies that furnished all or part of the data requested, and that information was the basis for emission factors and emission estimates set forth in this report.

All of the companies that produce boron were requested to provide the essential data required for the study. Information

was obtained from all of them. The manufacturers of end products that provided information represented about 30 percent of the industry capacity.

Regardless of the method selected, the first step to be taken when updating the emission estimates is to contact the United States Bureau of Mines to obtain the latest information concerning tonnages for domestic production, imports, exports, and the domestic uses.

When using Method A, the emission factors must be revised by contacting industry to determine the improvements in air pollution collection equipment efficiency and other processing changes affecting boron emissions. The revised emission factors may then be used with the production quantities obtained from the Bureau of Mines.

Method B is considerably shorter than Method A, and less reliable. The only requirement is to revise the material flow chart according to the most recent Bureau of Mines data and apply the emission factors shown in this report. In reality this method is only a partial updating. There is no determination regarding improvements in air pollution control, a shift in production to more efficient plants, or any other

considerations affecting emission factors. The advantage is that the report can be updated within a few days, rather than several months.

To update boron emissions from processing, glass production, ceramic coatings, and agricultural uses, it is preferable to use Method A. The remaining emissions shown in this report may be updated by Method B without introducing an appreciable error into the results.